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Distribution and conservation status of *Drosera viridis* Rivadavia (Droseraceae), including the first records from Rio Grande do Sul, Brazil, and a key to the genus in this state

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Abstract
Drosera viridis Rivadavia, a Brazilian endemic species of carnivorous herb, has its geographical range extended in South Brazil, including the first records for Rio Grande do Sul, from subtropical highland grasslands in the north-eastern region of the state. Taxonomic notes, habitat information, an updated distribution range, and an identification key for the *Drosera* L. species from Rio Grande do Sul are presented. Based on the updated distributional range and potential threats in Brazil, we suggest the species to be classified as Near Threatened, following IUCN Red List categories and criteria.

Keywords
Atlantic Rainforest, carnivorous plants, geographic distribution, highland grasslands, Red List.

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Introduction

Droseraceae is a cosmopolitan family of carnivorous herbs comprising three genera and about 250 species, which are restricted to nutrient-poor, mostly sandy, seasonally dry habitats (Fleischmann et al. 2018). In Brazil, the family is represented only by the genus *Drosera* L., with 31 species, one nothospecies, and two varieties, most of them reported for the Cerrado (20 spp.) and Atlantic Rainforest (13 spp.) domains (Gonella 2020). Four species have been recorded from Rio Grande do Sul state so far: *D. brevifolia* Pursh, *D. capillaris* Poir., *D. communis* A.St.-Hil., and *D. montana* A.St.-Hil.

During fieldwork carried out by the second author in northeastern Rio Grande do Sul state, a *Drosera* species was photographed in November 2019 and later collected in December 2019. Photographs of the species were posted on the Facebook group "Detweb", which is dedicated to plant identification by Brazilian botanists and enthusiasts, and a putative identification was suggested by the first author. Further analysis of the specimens and photographs confirmed this to be the first record of a fifth *Drosera* species from Rio Grande do Sul. This identification was further supported by a herbarium revision that revealed several new records of the same species. Hence, here we present an update of the current

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knowledge on the distribution and conservation of the species *Drosera viridis* Rivadavia, which was thus far only known from São Paulo, Paraná, and Santa Catarina states (Rivadavia 2003).

Methods

Collections in Rio Grande do Sul were conducted in December 2019 in the Canyon Montenegro, in the municipality of São José dos Ausentes, near the border with the state of Santa Catarina. The voucher was deposited at the HUCS herbarium, with a duplicate sent to SPF (acronyms according to Thiers 2020). In addition, extensive herbaria revision was carried out as part of an ongoing taxonomic revision of the genus *Drosera*, including herbarium specimens held at ALCB, B, BHCB, BM, CEN, CEPEC, CESJ, DIAM, ESA, ESAL, F, FLOR, G, HEPH, HUCS, HUEFS, HUFSJ, HUFU, IBGE, IAN, INPA, IPA, JPB, K, M, MAC, MBM, MBML, MO, NY, OUPR, P, PAMG, R, RB, RON, SP, SPF, UB, UEC, UFRN, US, VEN, VIES, and W. The identification was confirmed by consulting the protologue of the taxon (Rivadavia 2003) and the type material. The distribution map was prepared with the QGIS3 software (QGIS Development Team 2020) using layers available from IBGE (2020). Coordinates were obtained from the specimens' herbarium labels. For specimens without coordinates, secondary georeferencing was done based on locality information and coordinates are approximated. The geodetic datum used was WGS84.

The conservation status assessment followed IUCN Red List Categories and Criteria (IUCN 2012), and the extent of occurrence (EOO) and area of occupancy (AOO) were estimated with GeoCAT (Bachman et al. 2011), with the employment of the standard IUCN cell size of 4 km^2 for the AOO estimation.

Results

Drosera viridis **Rivadavia**, Carnivorous Plant Newsletter 32: 87. 2003. Type: Brazil, São Paulo, Paranapiacaba, 02 Feb. 1996, *Rivadavia-Lopes & Cardoso 510* (holotype SPF 158000!, isotypes MBM 287295!, NY 00688466!, R 210202!).
Figures 1, 2

The new record and additional specimens examined complements the list of specimens (holotype, isotypes, and paratypes) cited by Rivadavia (2003), all of which have been personally studied by the first author.

New record. BRAZIL • **Rio Grande do Sul**, São José dos Ausentes, Canyon Montenegro; 28°36′53.34″S, 049° 47′37.68″W; 1302 m elev.; 27 Dec. 2019; *C.R. Lehn 2566* (HUCS; SPF).

Additional specimens examined. BRAZIL. **Paraná** • Campo Largo, Serra de São Luís; 25°27′52.1″S, 049° 39′04.8″W; 1170 m elev.; 25 Nov. 2006; *F. Rivadavia & C. Rohrbacher 2443* (SPF) • Balsa Nova; 25°26′27.01″S, 049°43′29.56″W; 1050 m elev.; 02 Nov. 2010; *A. Alves 7* (SPF) • ibid.; 25°28′10.52″S, 049°39′07.96″W; 1180 m elev.; 11 Dec. 2011; *A. Alves 23* (SPF) • ibid.; 25°32′18.86″S, 049°42′52.69″W; 950 m elev.; 24 Nov. 2013; *A. Alves 45* (SPF) • Palmeira, Rio das Pombas; 25°26′30.7″S, 049° 44′34.4″W; 1000 m elev.; 25 Nov. 2006; *F. Rivadavia & C. Rohrbacher 2448* (SPF) • ibid.; 25°28′07.77″S, 049° 46′20.19″W; 970 m elev.; 18 Nov. 2012; *A. Alves & E. Borges 34* (SPF) • ibid.; 25°22′29″S, 049°48′40″W; 17 Dec. 2013; *E.D. Lozano 2383* (MBM) • Ponta Grossa, Parque Estadual de Vila Velha; 25°14′51″S, 049°59′31″W; 18 Dec. 2013; *E.D. Lozano 2427* (MBM) • Tibagi, Sítio Sete Quedas; 24°35′02.6″S, 050°15′42.3″W; 1096 m elev.; 28 Nov. 2013; *M.G. Caxambu et al. 4945* (MBM) • **Rio Grande do Sul**, Cambará do Sul; [Parque Nacional da Serra Geral], [Canyon] Fortaleza; 27 Sep. 1992; 1100 m elev.; *R.L. Barbieri s.n.* (HUCS 12638a; mixed with *D. brevifolia*) • **Santa Catarina**, Campo Alegre, Campos do Quiriri; 26°16′57″S, 048°59′14.79″W; 1348 m elev.; 17 Nov. 2012; *C.V. Silva et al. 24* (JPB) • Mafra, Campo São Lourenço; 26°10′25.78″S, 045°54′16.16″W; 878 m elev.; 18 Jan. 2014; *V. Antunes Filho 1* (SPF) • Santa Cecília, Serra do Espigão; 26°45′29.05″S, 050°20′50.84″W; 1167 m elev.; 22 Feb. 2014; *V. Antunes Filho 2* (SPF) • **São Paulo**, Embu-Guaçu, distrito de Cipó; 23°54′00.3″S, 046°45′00″W; 750 m elev.; 11 Mar. 2006; *F. Rivadavia & V.O. Miranda 2143* (SPF) • ibid.; 17 Apr. 2011; *P.M. Gonella & A. Fleischmann 255* (SPF) • Itararé, fazenda Ibiti; 24°14′S, 049°16′W; 1200 m elev.; 26 Nov. 1993; *V.C. Souza et al. 4827* (ESA; UEC).

Identification. According to Rivadavia (2003; complemented in square brackets), *Drosera viridis* is most similar to *D. communis*, from which it can be distinguished by its overall larger size [when growing syntopic]; leaves always green [to reddish at the base of petiole; see Fig. 1C], never turning [entirely deep] red even when exposed to direct sunlight; the winged petioles with eglandular-pubescence present only on the margins; the indistinct stigmata, and rectangular seeds. It is further distinguished by the erect to slightly curved base of the scape (Fig. 1C), while in *D. communis* it is pronouncedly curved, often hook-shaped (arcuately ascending).

The species is endemic to Brazil, occurring in the states of Paraná, Santa Catarina, São Paulo, and Rio Grande do Sul (new records reported here; Fig. 2), while *D. communis* occurs in Colombia, Venezuela, Bolivia, Argentina, Paraguay, and Brazil (being recorded from 16 states across the five Brazilian major regions, including the four states where *D. viridis* occurs; Gonella 2020).

Extensive study of herbarium specimens, including the type specimens of both taxa, and plants *in situ* supports the differences cited by Rivadavia (2003), with the indumentum distribution, scape curvature at the base, and seed shape being the most consistent characters to distinguish between *D. viridis* and *D. communis* when both taxa are syntopic or sympatric. Variation

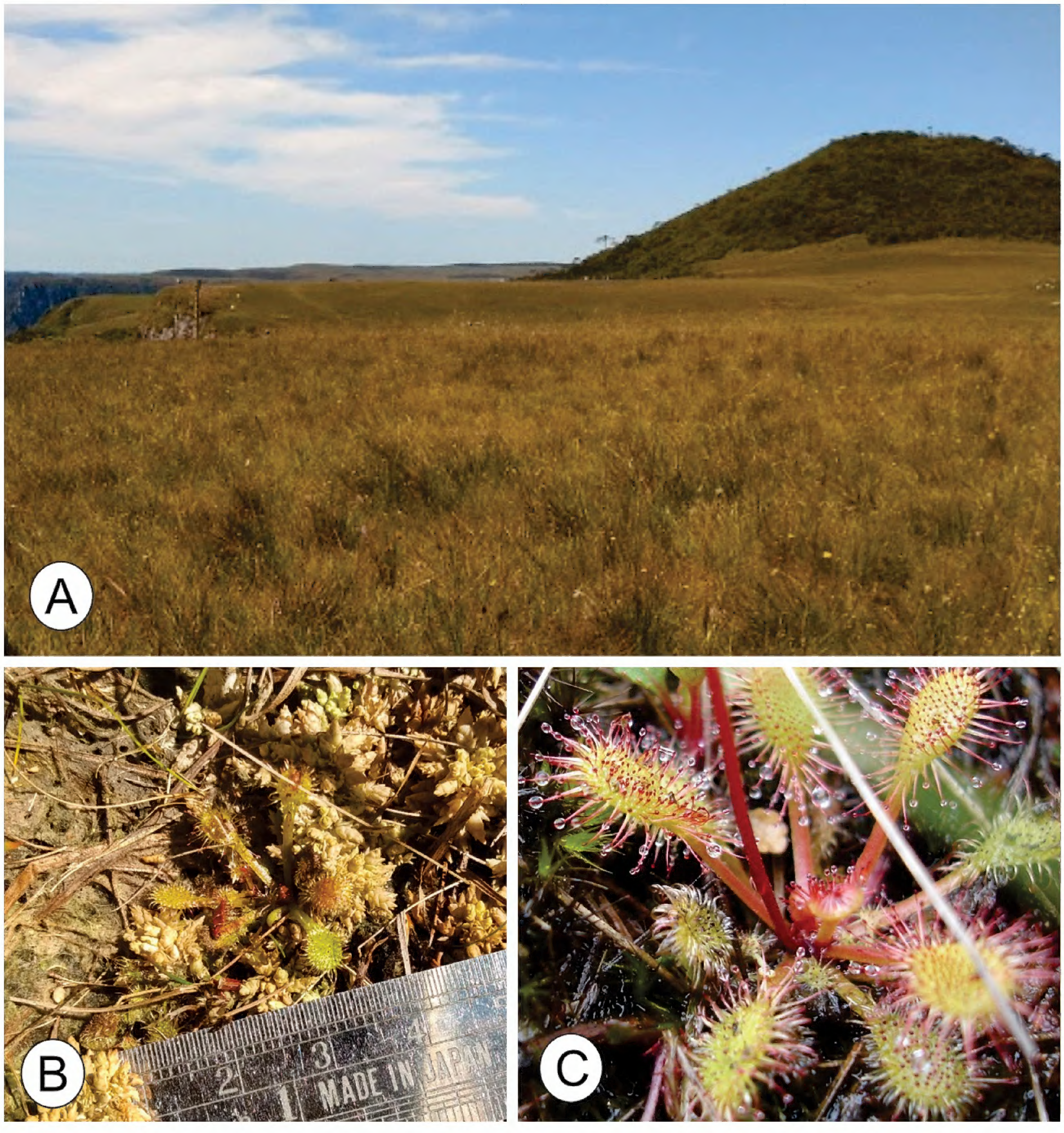

Figure 1. A. Subtropical highland grasslands on the Canyon Montenegro (RS), habitat of *Drosera viridis*. **B.** *Drosera viridis* recorded from the Canyon Montenegro (specimen *C.R. Lehn 2566*). **C.** *Drosera viridis* from Campo Alegre, Santa Catarina (represented by the specimen *C.V. Silva et al. 24*). Photographs by CRL (A, B) and Felipe Steinthaler (C).

in indumentum distribution is observed in *D. communis* across its much wider distribution range, but in the areas where the species is sympatric with *D. viridis*, it presents denser indumentum of eglandular trichomes on the abaxial and adaxial petiole surfaces. However, contrary to Rivadavia (2003) who stated that the leaves of *D. viridis* are always entirely green, *in situ* and cultivation observations show that the species often possess the petiole bases dyed reddish green, turning entirely (yellowish) green towards the apex and leaf blade. Nevertheless, when found growing under the same conditions of light and soil, *D. viridis* and *D. communis* always present different colorations, the latter showing a redder coloration that extends to the whole leaf.

Discussion

Drosera viridis was described based on a set of specimens from São Paulo, Paraná, and Santa Catarina states, in Southeast and South Regions of Brazil, where it is endemic to the Atlantic Rainforest domain and found in wet to waterlogged soils of highland grasslands vegetation (Rivadavia 2003; Gonella 2020).

Rivadavia (2003) already highlighted that *D. viridis* might be more widespread in the states of southern Brazil. Until his work, only a single specimen, from the municipality of Irani, was known from Santa Catarina state. Indeed, our findings include new records for Santa Catarina, and also the first records from Rio Grande do

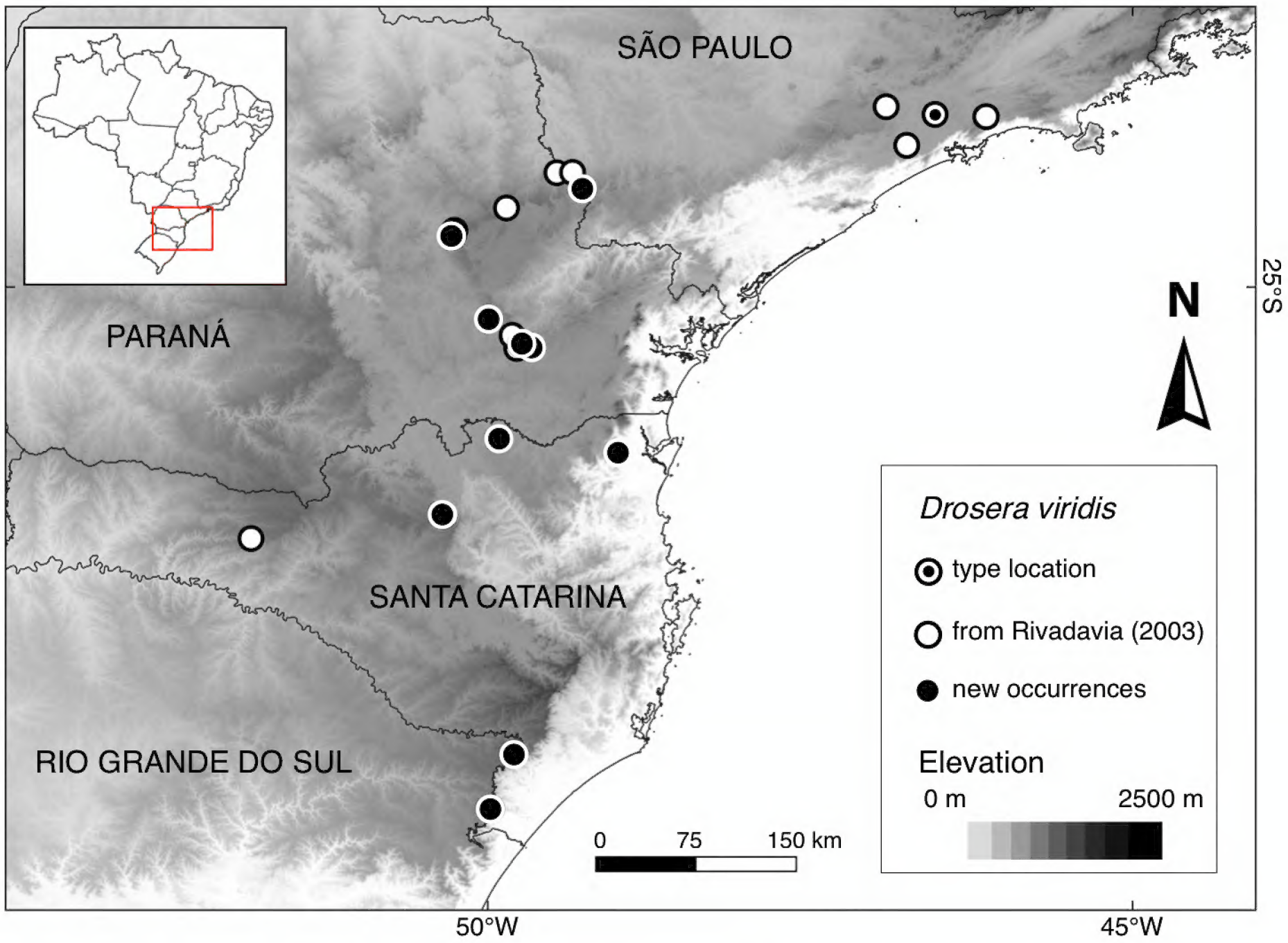

Figure 2. Distribution map of *Drosera viridis*, highlighting the records known prior to this work (cited by Rivadavia 2003), the occurrences newly reported here, and the type location.

Sul (Fig. 2). The new southernmost record, from Cambará do Sul (Rio Grande do Sul), expands the distributional range of the species by 292 km to the southeast from Irani (Santa Catarina).

Our work almost doubles the number of known herbarium specimens of *D. viridis*: 20 specimens are cited by Rivadavia (2003), and 17 new specimens are added here. Several specimens, however, are from the same locations or recorded very close to those cited by Rivadavia (2003; Fig. 2). These new specimens include the first specimen unequivocally recorded from a conservation unit [*E.D. Lozano 2427* (MBM)], from the Parque Estadual de Vila Velha, municipality of Ponta Grossa, Paraná. Previous records cited by Rivadavia (2003) might also come from state parks in Paraná, such as the Parque Estadual do Guartelá [*F. Rivadavia-Lopes et al. 402* (SPF)] and Parque Estadual Vale do Codó (several specimens cited from the municipality of Jaguariaíva); however, these cannot be confirmed due to lack of georeferenced data. The species also occurs in the Parque Nacional da Serra Geral, as one of the new records we present here is from Canyon Fortaleza [*R.L. Barbieri s.n.* (HUCS 12638a); also without georeferenced data], included within such conservation unit.

One of the newly reported populations from Rio Grande do Sul [represented by the collection *C.R. Lehn 2566* (HUCS, SPF); Fig. 1B] was composed by a few scattered individuals inhabiting a peatbog with the presence of the moss *Sphagnum* L. (Sphagnaceae), along touristic trekking trails in the border of the plateau at an elevation of 1302 m a.s.l. (Fig. 1A). This is the second highest record of the species; the highest is also recorded here at an elevation of 1348 m a.s.l., in the Serra do Quiriri, municipality of Campo Alegre, Santa Catarina [*C.V. Silva et al. 24* (JPB); see Fig. 1C]. These new records expand the maximum elevation at which *D. viridis* was recorded by almost 250 m above the range between 500–1100 m a.s.l. presented by Rivadavia (2003).

In Rio Grande do Sul, *D. viridis* is sympatric and syntopic with *D. montana* (pers. obs.) and *D. brevifolia* (as suggested by the mixed collection *R.L. Barbieri s.n.*). These two latter species occupy a wider range of habitats throughout their range (Rivadavia et al. 2014; Gonella 2020), but in the highland grasslands vegetation they are usually associated with areas of wet soils and along stream margins. To allow the precise identification of *Drosera* specimens from Rio Grande do Sul, we provide an updated key to all species occurring in that state below.

Key to the *Drosera* species from Rio Grande do Sul, Brazil (adapted from Gonella 2020):

1 Stipules absent, or with only two setae at the lateral base of the leaves ..... *D. brevifolia*

1′ Stipules developed, intrapetiolar, papery 2
2 Leaves oblong or oblong-spatulate, with petiole indistinct, gradually widening towards an oblong lamina; scape base densely glandular-pilose..... ..... *D. montana*
2′ Leaves spatulate, with petiole distinct, abruptly widening towards an obovate to suborbicular lamina; scape base glabrous to sparsely eglandular-pilose only 3
3 Scape, pedicels and sepals entirely glabrous..... *D. capillaris*
3′ Scape base sparsely eglandular-pilose to glabrous, apex, pedicels and sepals glandular-pilose..... 4
4 Leaves with eglandular pubescence distributed on both the adaxial and abaxial surfaces of the petioles; scape base conspicuously curved (arcuately curved); seeds fusiform ..... *D. communis*
4′ Leaves with eglandular pubescence restricted to the margins of the petiole; scape base slightly curved to erect; seeds rectangular ..... *D. viridis*

Threats and conservation status. As highlighted before, *D. viridis* is endemic to the Atlantic Rainforest domain in Southeast and South regions of Brazil (Fig. 2), where is found in open areas in wet to waterlogged soils of subtropical highland grasslands (Fig. 1A; Rivadavia 2003; Gonella 2020).

Despite its broad distribution range in four Brazilian states, resulting in an Extent of Occurrence (EOO) of 159,234 km^2, *D. viridis* shows a small Area of Occupancy (AOO = 88 km^2). While this AOO could still be underestimated, as implied by the large number of new records uncovered since the first description of the species, the specific habitat requirements of the species limit its potential distribution. Additionally, the calculated EOO include large areas of unsuitable habitats for *D. viridis* and, therefore, is overestimated.

The highland grasslands areas of the Atlantic Rainforest domain have been considerably transformed and suppressed over the past decades, being mostly destined for livestock, agriculture, and silviculture (Overbeck et al. 2007). Habitat loss and transformation are the main threats to the native and endemic flora of these grasslands, further promoting fragmentation of remnant habitats, leading to reduction of species richness, and biotic homogenization (Staude et al. 2018). The *Campos de Cima da Serra*, a highland grasslands region of Rio Grande do Sul from where the two new records of *D. viridis* from the state are recorded, lost 17% of natural grassland area within a period of 6 years (from 2002/2003 to 2008/2009), being largely destined to silviculture (Hermann et al. 2016).

One of the main timber species used in silviculture in southern Brazil is *Pinus elliottii* Engelm. (Pinaceae), recognized as an invasive species in grassland areas in various areas worldwide (Global Invasive Species Database 2020). Such species have already been recognized as an important invasive species in grassland areas in eastern Paraná state (Ziller and Galvão 2002), where *D. viridis* is native.

Furthermore, livestock activities are directly associated with the introduction of exotic and invasive grass species that compete for space and light with native species, altering ecosystem processes such as microclimate, changing the fire cycle, and increasing the fragmentation of habitats, often leading to local extinctions (D'Antonio and Vitousek 1992; Gilbert and Levine 2013).

Finally, some of the populations of the species are affected by human intrusion to the habitat, exemplified by the type locality of *D. viridis* (Fig. 2), which was recorded from a ditch by a roadside (Rivadavia 2003). The first author revisited that *locus classicus* in April 2010 and no plants were found, suggesting it may have been extirpated at the site due to road clearing and maintenance. Another example comes from one of the new records here reported: in the Canyon Montenegro area, the species occurs along a trekking trail, exposing it to trampling.

Throughout its range, *D. viridis* is known to occur inside conservation units in Paraná and Rio Grande do Sul (see above); however, the size and conservation status of these populations are unknown.

According to a GeoCAT assessment, *D. viridis* could either be eligible to the categories of Least Concern (based on the EOO larger than 20,000 km^2) or Endangered (based on the AOO smaller than 500 km^2) following the area requirements (criterion B) for these categories by IUCN (2012). However, based on the aforementioned information regarding habitat degradation, the species qualifies only for criterion B2b (continuing decline of habitat quality, AOO and EOO), which is not enough for it to be classified as Endangered, as it is known from more than five locations (criterion B2a) and there is no evidence for extreme fluctuations of area or population sizes (criterion B2c). Therefore, according to the Guidelines for Using the IUCN Red List Categories and Criteria (IUCN Standards and Petitions Committee 2019), *D. viridis* is to be classified as Near Threatened, as it partially meets the criteria for the Endangered category and the described threats can cause it to be classified in one of the threatened categories in a near future.

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Authors' Contributions

PMG and CRL performed field records, and wrote the manuscript; PMG revised herbarium specimens and prepared the distribution map; CRL prepared the figure plate.

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